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Manapragada

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(54) **METHOD AND APPARATUS FOR PROCESSING BANDWIDTH INTENSIVE DATA STREAMS USING VIRTUAL MEDIA ACCESS CONTROL AND PHYSICAL LAYERS**

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**
H04W 16/26 (2009.01)

(52) **U.S. Cl.**
CPC ***H04W 16/26*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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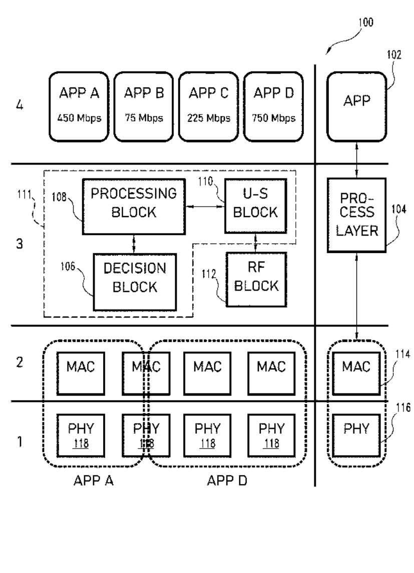
(57) **ABSTRACT**

A wireless networking system is disclosed. The wireless networking system includes an application layer associated with one or more applications having a wireless bandwidth requirement. A first wireless transceiver resource associated with an actual MAC layer and PHY layer is employed. The first wireless transceiver resource has a first bandwidth availability up to a first actual bandwidth. A second wireless transceiver resource associated with the actual MAC layer and the PHY layer is employed. The second wireless transceiver resource has a second bandwidth availability up to a second actual bandwidth. A processing layer evaluates the wireless bandwidth requirement and the first and second bandwidth availabilities of the wireless transceiver resources. The processing layer includes a bandwidth allocator to allocate at least a portion of each of the first and second actual bandwidths to virtual MAC and virtual PHY layers, and to satisfy the application layer wireless bandwidth requirement.

30 Claims, 11 Drawing Sheets



Related U.S. Application Data

No. 16/039,660, filed on Jul. 19, 2018, now Pat. No. 11,115,834, which is a continuation of application No. 14/526,799, filed on Oct. 29, 2014, now Pat. No. 10,034,179.

(60) Provisional application No. 61/897,219, filed on Oct. 30, 2013, provisional application No. 61/897,216, filed on Oct. 30, 2013.

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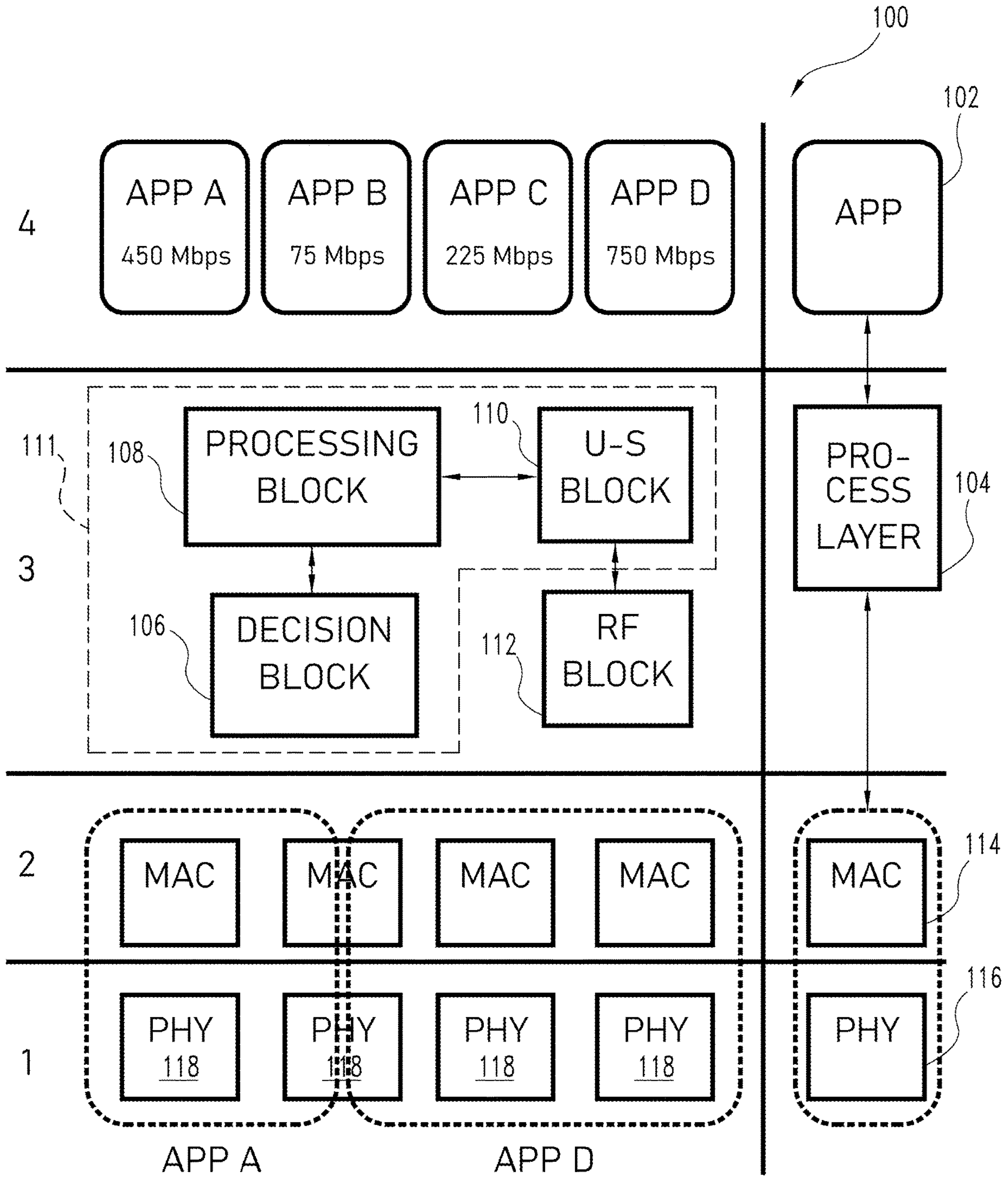
100
102
4
APP A
450 Mbps
APP B
75 Mbps
APP C
225 Mbps
APP D
750 Mbps
APP
111
108
PROCESSING BLOCK
110
U-S BLOCK
PRO-CESS LAYER
104
3
106
DECISION BLOCK
112
RF BLOCK
2
MAC
MAC
MAC
MAC
MAC
114
116
1
PHY 118
PHY 118
PHY 118
PHY 118
PHY
APP A
APP D

Fig. 1

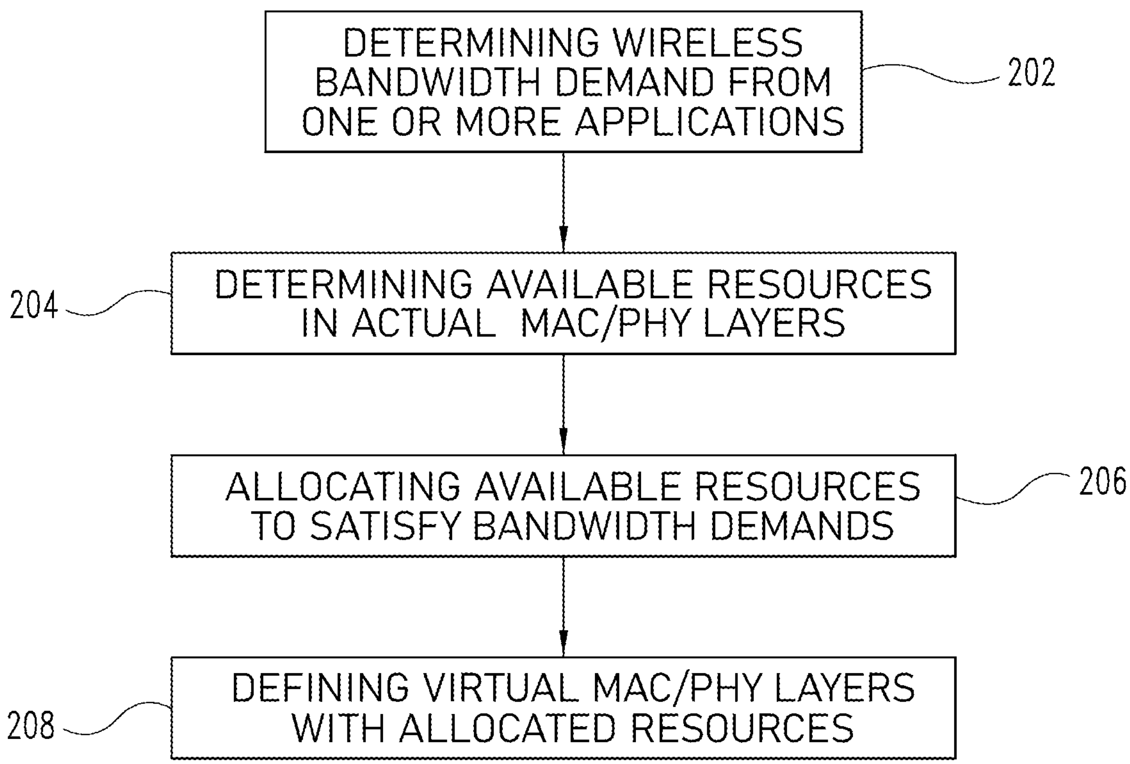
DETERMINING WIRELESS BANDWIDTH DEMAND FROM ONE OR MORE APPLICATIONS
202
204
DETERMINING AVAILABLE RESOURCES IN ACTUAL MAC/PHY LAYERS
ALLOCATING AVAILABLE RESOURCES TO SATISFY BANDWIDTH DEMANDS
206
208
DEFINING VIRTUAL MAC/PHY LAYERS WITH ALLOCATED RESOURCES

Fig. 2

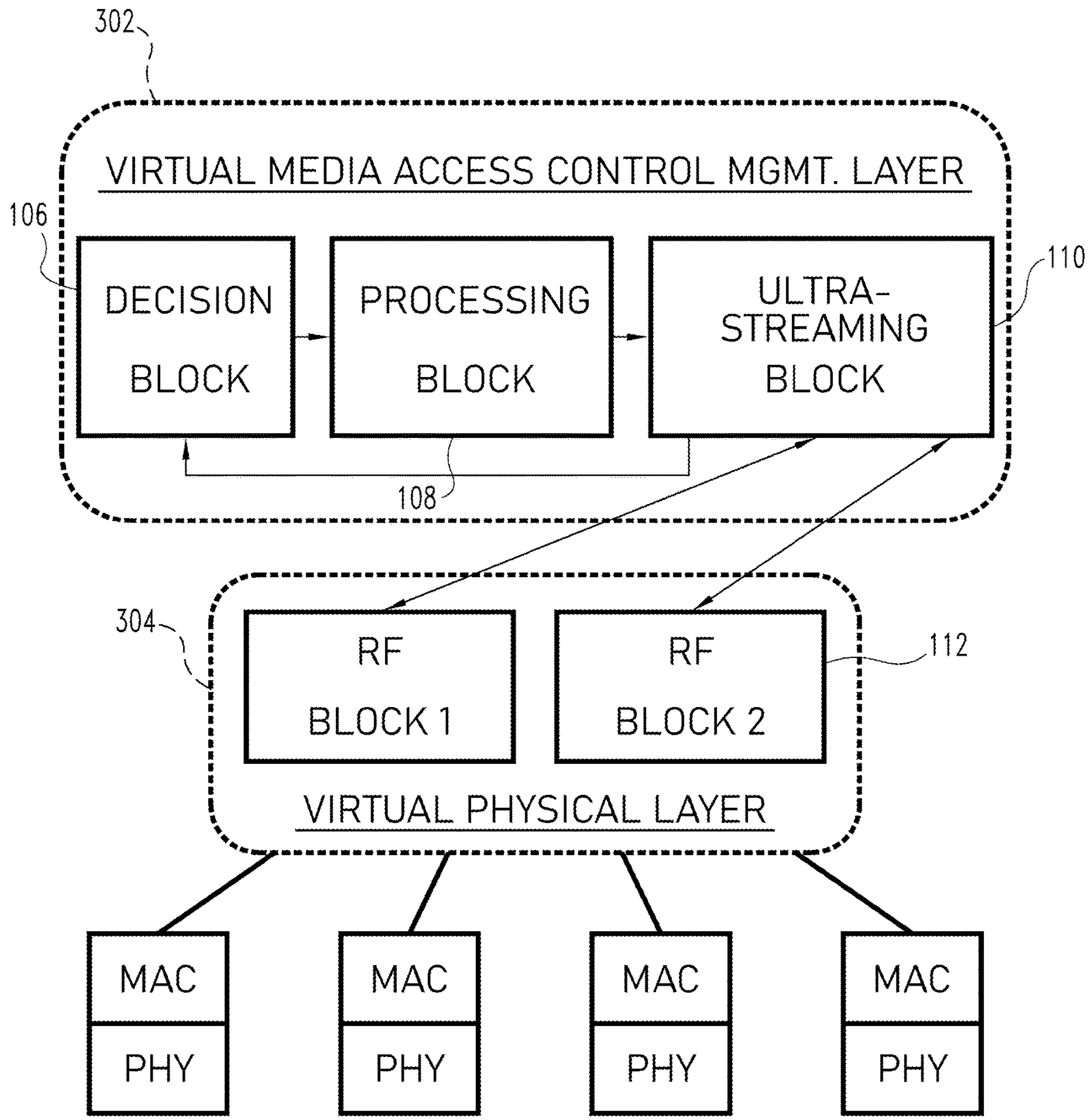
302
VIRTUAL MEDIA ACCESS CONTROL MGMT. LAYER
106
DECISION BLOCK
PROCESSING BLOCK
ULTRA-STREAMING BLOCK
110
108
304
RF BLOCK 1
RF BLOCK 2
112
VIRTUAL PHYSICAL LAYER
MAC
PHY
MAC
PHY
MAC
PHY
MAC
PHY

Fig. 3

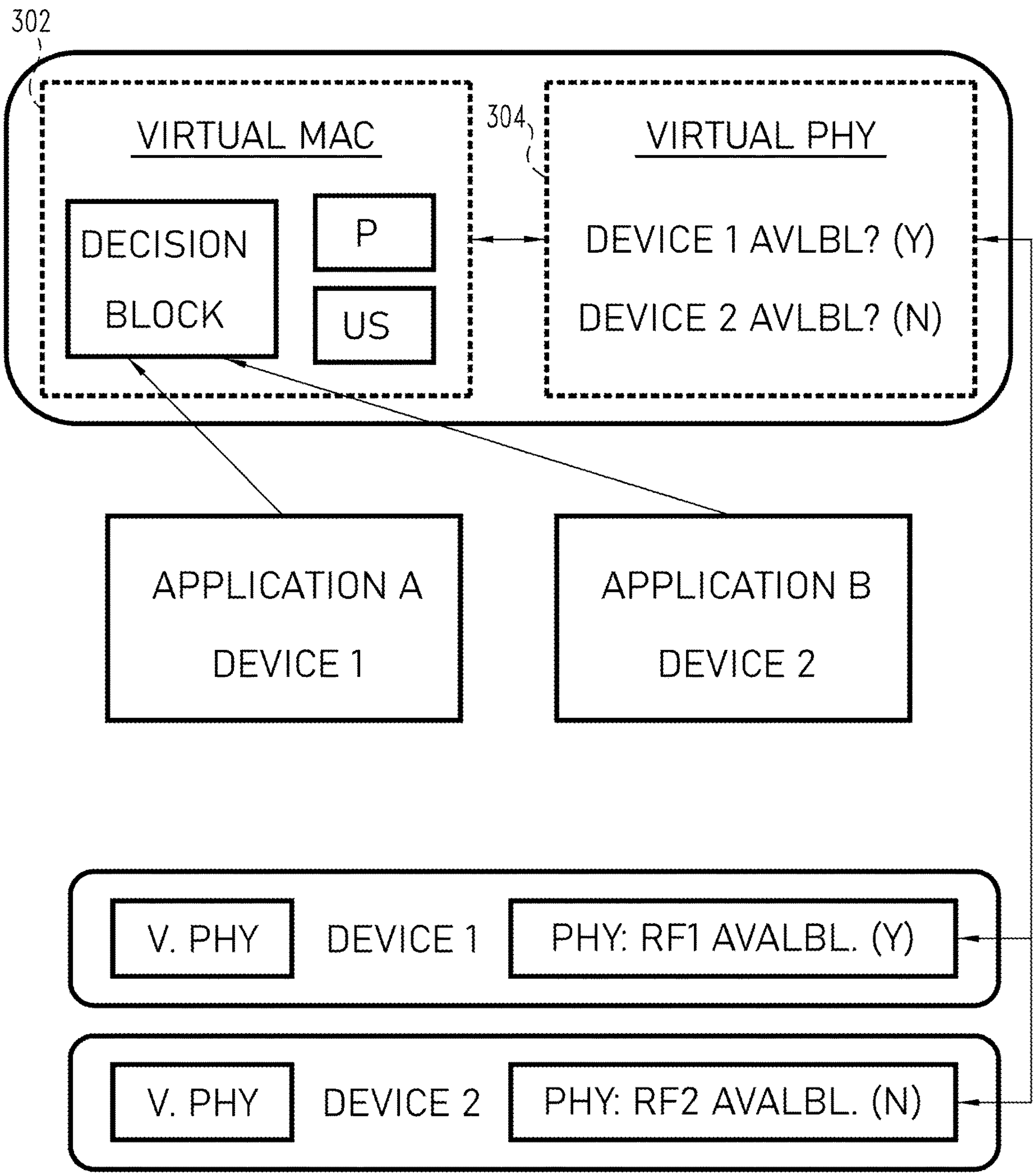
302
VIRTUAL MAC
DECISION BLOCK
P
US
304
VIRTUAL PHY
DEVICE 1 AVLBL? (Y)
DEVICE 2 AVLBL? (N)
APPLICATION A
DEVICE 1
APPLICATION B
DEVICE 2
V. PHY
DEVICE 1
PHY: RF1 AVALBL. (Y)
V. PHY
DEVICE 2
PHY: RF2 AVALBL. (N)

Fig. 4

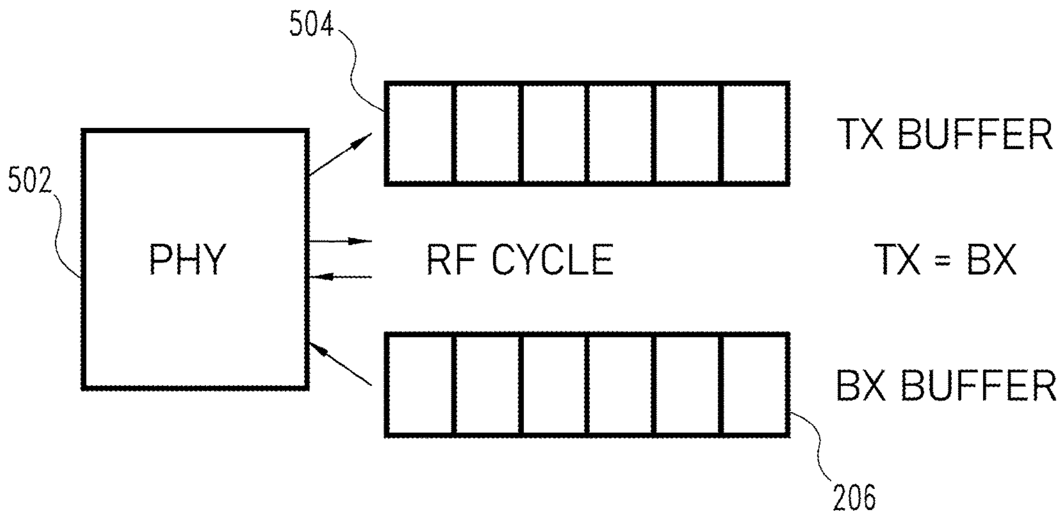
504
502
PHY
TX BUFFER
RF CYCLE
TX = BX
BX BUFFER
206

Fig. 5A

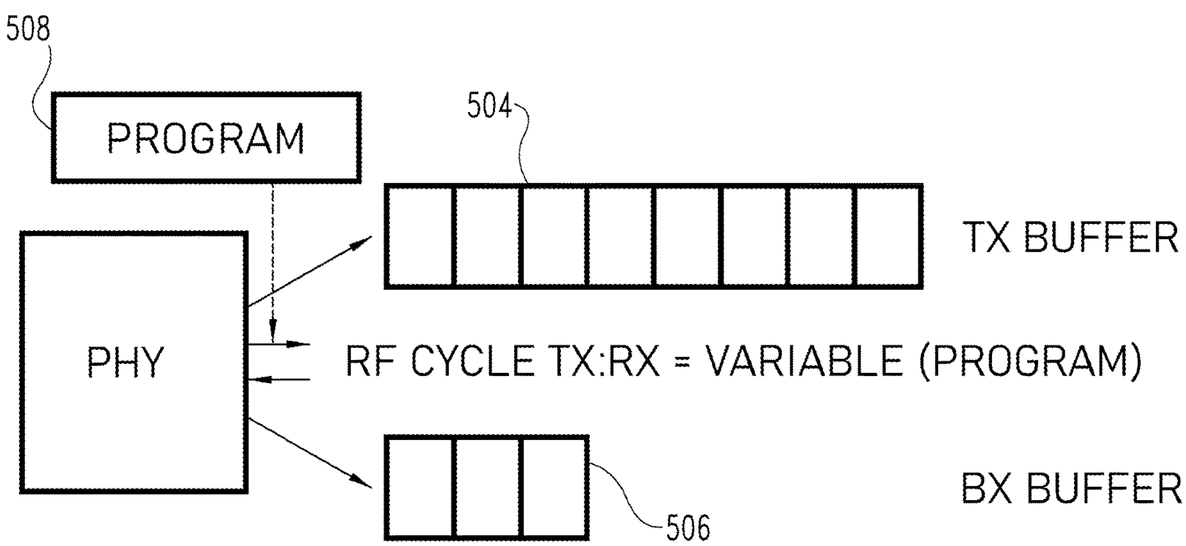
508
PROGRAM
504
PHY
TX BUFFER
RF CYCLE TX:RX = VARIABLE (PROGRAM)
BX BUFFER
506

Fig. 5B

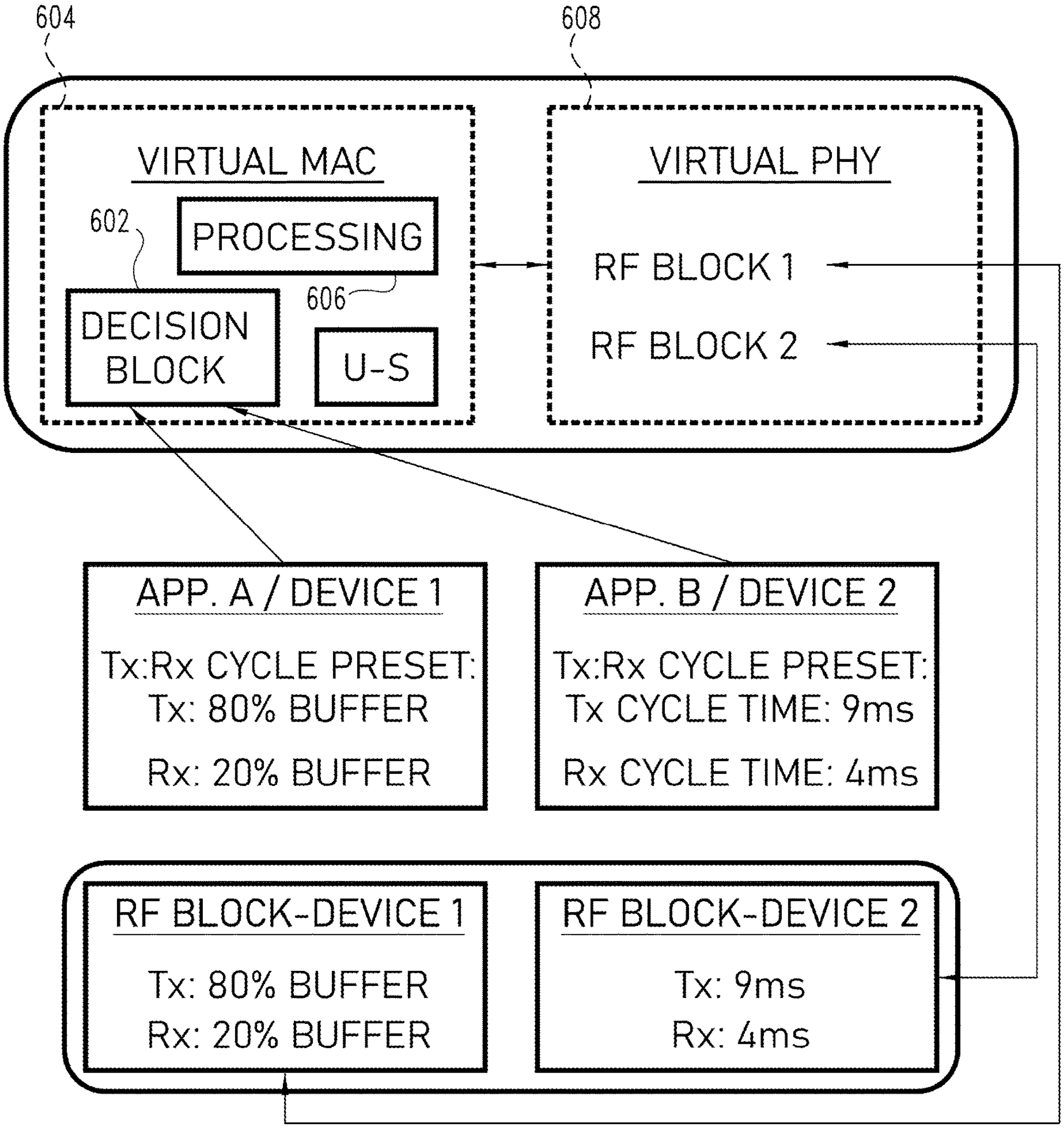
604
608
VIRTUAL MAC
602
PROCESSING
606
DECISION BLOCK
U-S
VIRTUAL PHY
RF BLOCK 1
RF BLOCK 2
APP. A / DEVICE 1
Tx:Rx CYCLE PRESET:
Tx: 80% BUFFER
Rx: 20% BUFFER
APP. B / DEVICE 2
Tx:Rx CYCLE PRESET:
Tx CYCLE TIME: 9ms
Rx CYCLE TIME: 4ms
RF BLOCK-DEVICE 1
Tx: 80% BUFFER
Rx: 20% BUFFER
RF BLOCK-DEVICE 2
Tx: 9ms
Rx: 4ms

Fig. 6

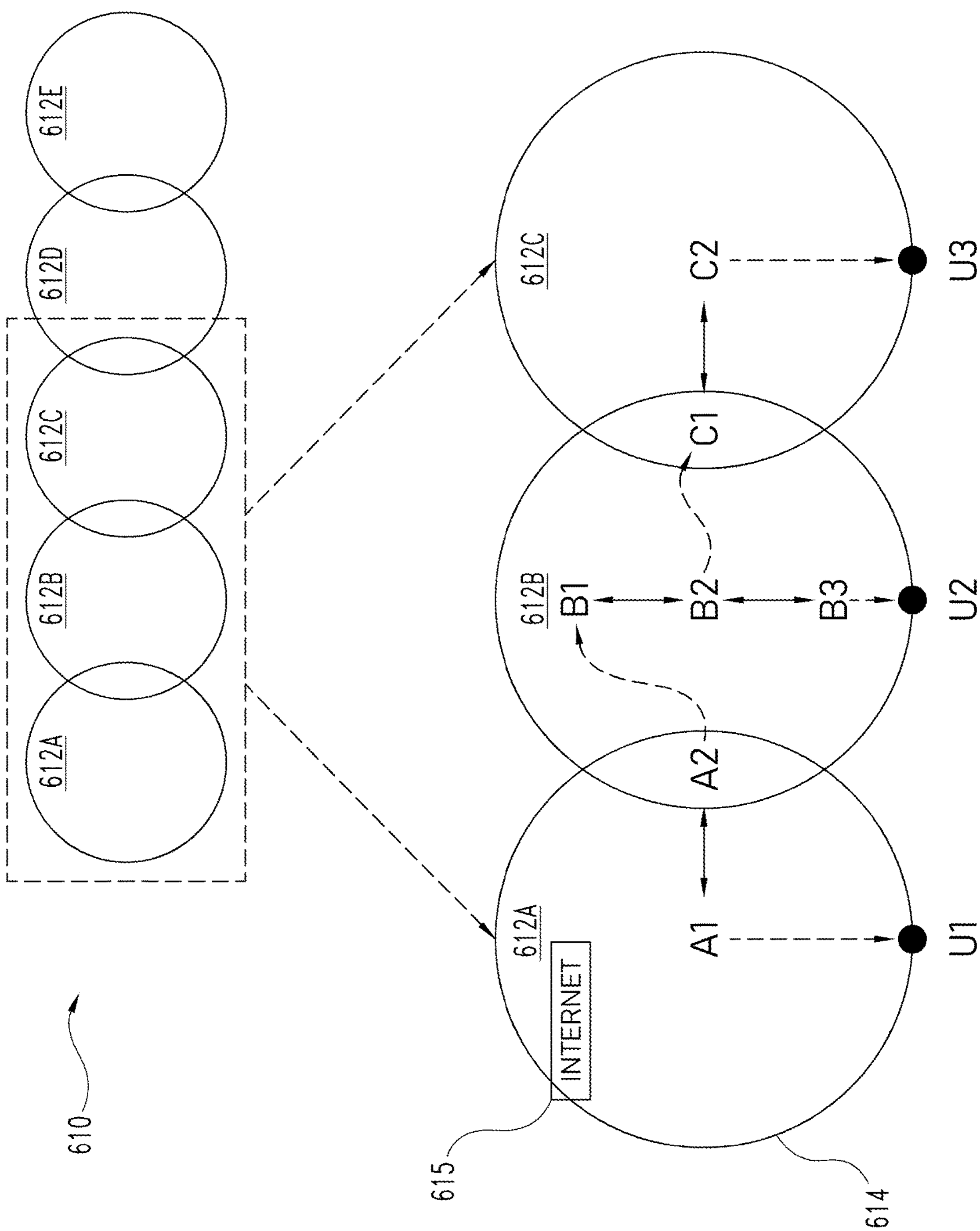
610
612A
612B
612C
612D
612E
612A
612B
612C
INTERNET
615
614
A1
A2
B1
B2
B3
C1
C2
U1
U2
U3

Fig. 7

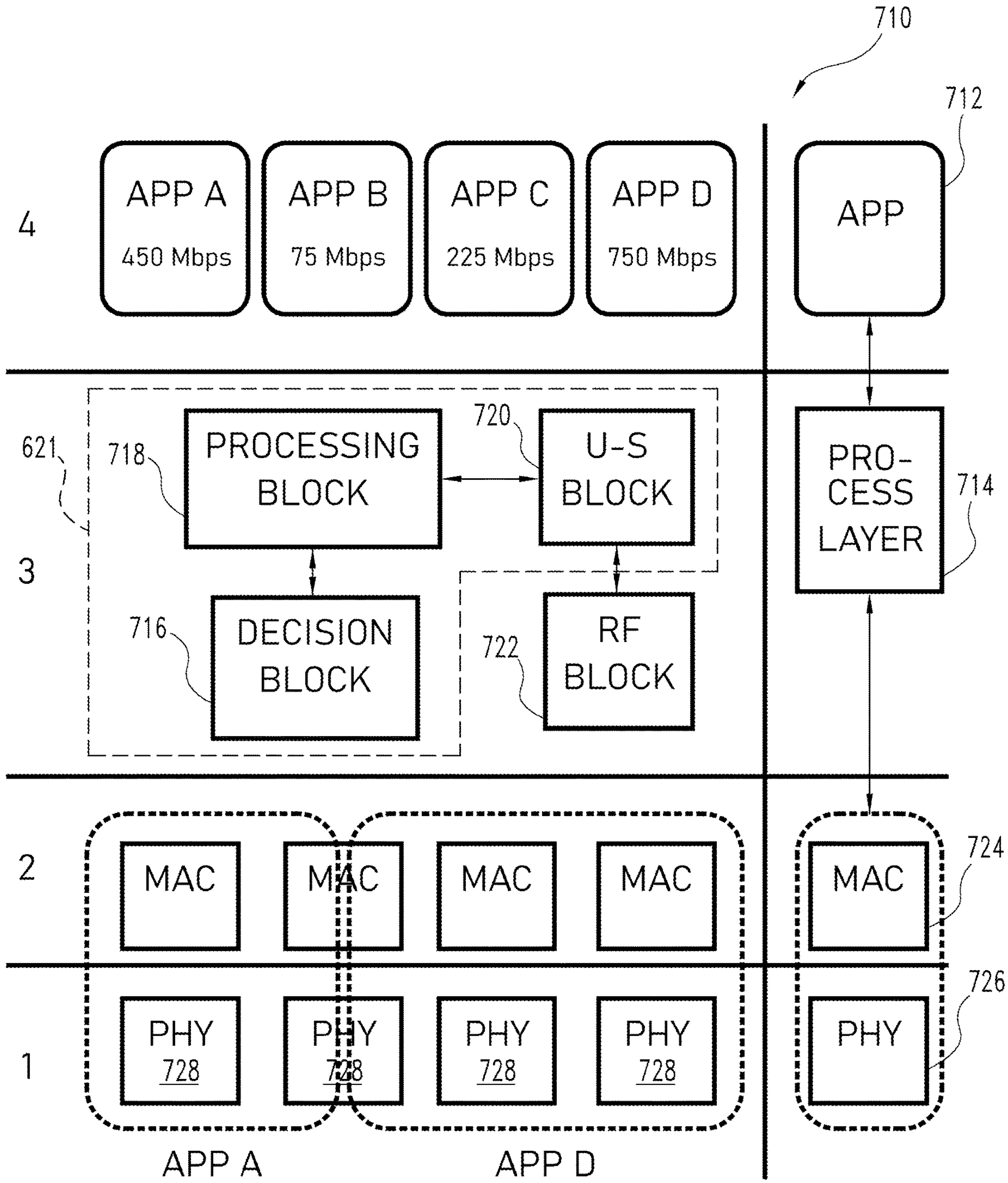
710
712
4
APP A
450 Mbps
APP B
75 Mbps
APP C
225 Mbps
APP D
750 Mbps
APP
3
621
718
PROCESSING BLOCK
720
U-S BLOCK
PRO-CESS LAYER
714
716
DECISION BLOCK
722
RF BLOCK
2
MAC
MAC
MAC
MAC
MAC
724
1
PHY 728
PHY 728
PHY 728
PHY 728
PHY
726
APP A
APP D

Fig. 8

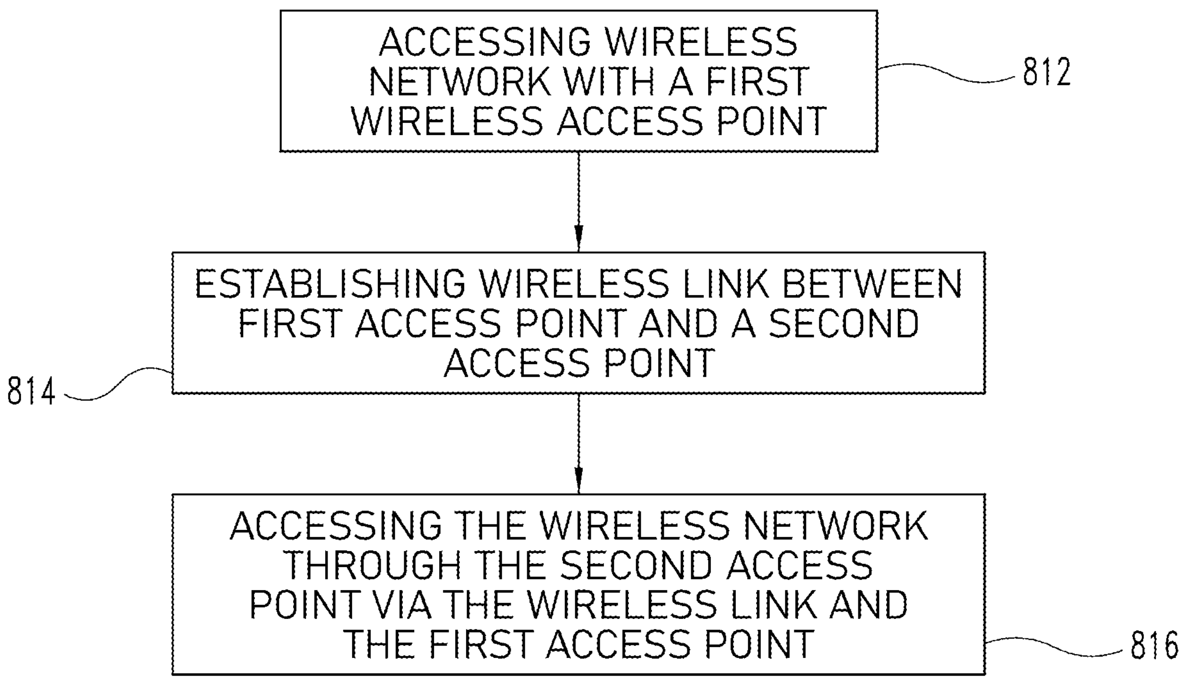
ACCESSING WIRELESS NETWORK WITH A FIRST WIRELESS ACCESS POINT
812
ESTABLISHING WIRELESS LINK BETWEEN FIRST ACCESS POINT AND A SECOND ACCESS POINT
814
ACCESSING THE WIRELESS NETWORK THROUGH THE SECOND ACCESS POINT VIA THE WIRELESS LINK AND THE FIRST ACCESS POINT
816

Fig. 9

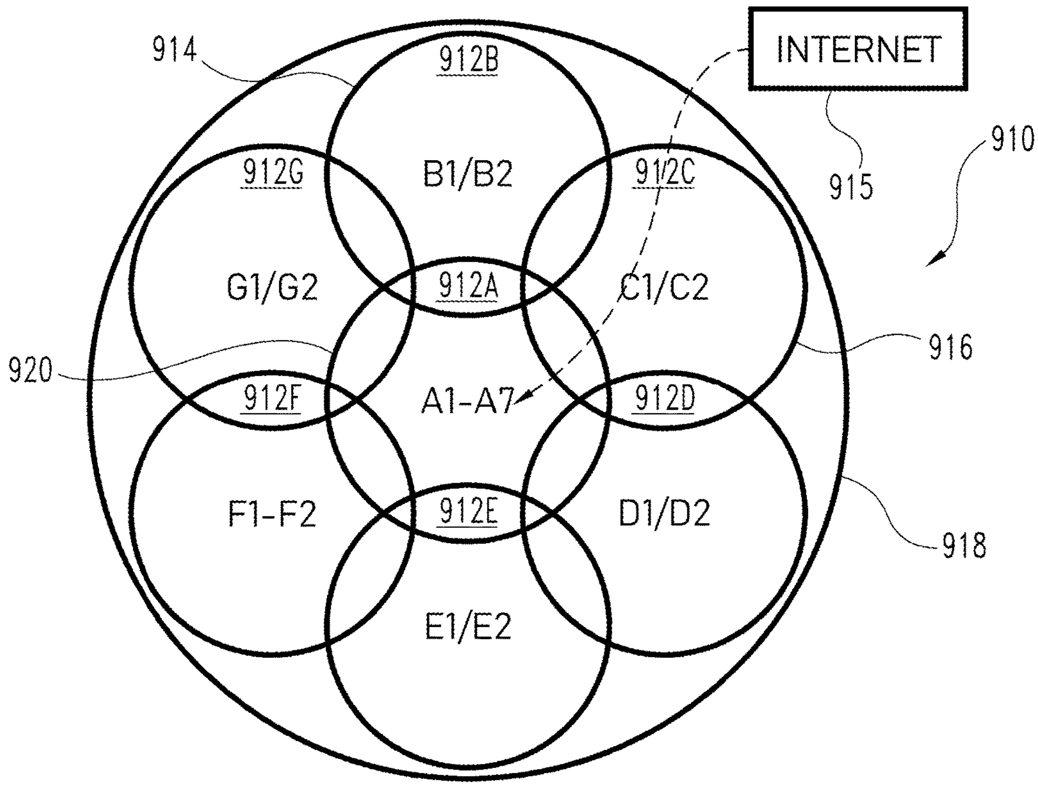

Fig. 10A

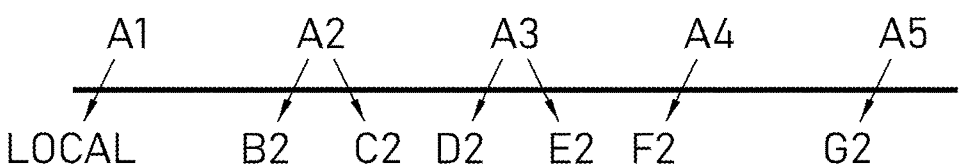

Fig. 10B

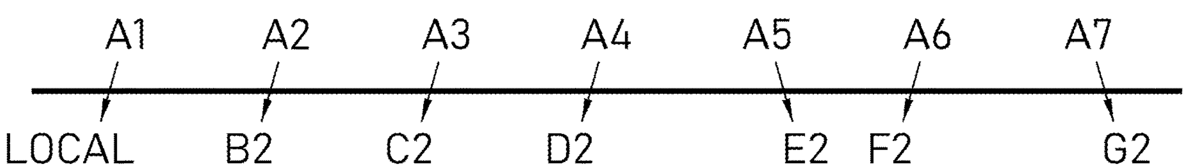

Fig. 10C

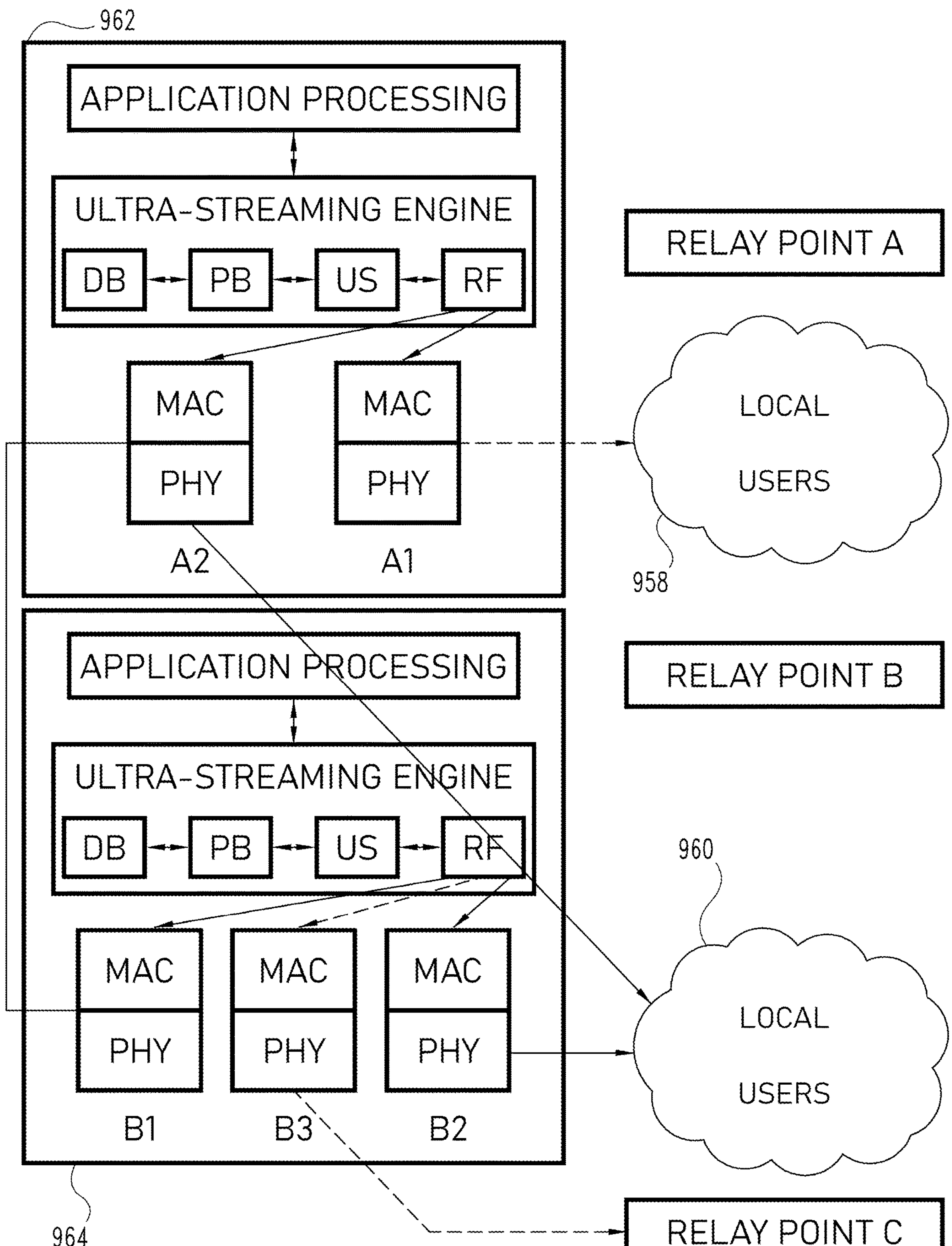
962
APPLICATION PROCESSING
ULTRA-STREAMING ENGINE
DB
PB
US
RF
MAC
PHY
MAC
PHY
A2
A1
RELAY POINT A
LOCAL
USERS
958
APPLICATION PROCESSING
ULTRA-STREAMING ENGINE
DB
PB
US
RF
MAC
PHY
MAC
PHY
MAC
PHY
B1
B3
B2
RELAY POINT B
960
LOCAL
USERS
964
RELAY POINT C

Fig. 11

METHOD AND APPARATUS FOR PROCESSING BANDWIDTH INTENSIVE DATA STREAMS USING VIRTUAL MEDIA ACCESS CONTROL AND PHYSICAL LAYERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 17/468,509 filed Sep. 7, 2021, titled "Method and Apparatus for Processing Bandwidth Intensive Data Streams Using Virtual Media Access Control and Physical Layers", which claims the benefit of U.S. patent application Ser. No. 16/039,660, filed Jul. 19, 2018, titled "System and Method For Extending Range and Coverage of Bandwidth Intensive Wireless Data Streams", now U.S. Pat. No. 11,115,834, which claims the benefit of U.S. patent application Ser. No. 14/526,799, filed Oct. 29, 2014, titled "System and Method For Extending Range and Coverage of Bandwidth Intensive Wireless Data Streams", now U.S. Pat. No. 10,034,179, which claims the benefit of U.S. Provisional Patent Application Ser. No. 61/897,219, filed Oct. 30, 2013, and U.S. Provisional Patent Application Ser. No. 61/897,216, filed Oct. 30, 2013, all of which are incorporated by reference herein in their entirety.

TECHNICAL FIELD

The disclosure herein relates to wireless networks, and more specifically to high-bandwidth wireless networks for distributing multi-media content.

BACKGROUND

Wireless networks may take many forms, depending on the application. Various WiFi standards exist where users within range of a "hotspot" may establish a wireless link to access a given network. A given hotspot, or wireless access point, typically has a limited range and coverage area. WiFi and cellular technologies rely on very different wireless radios and data protocols in transferring data over the network.

With the proliferation of multi-media content over wireless networks comes an insatiable demand for more bandwidth over the networks. Conventional wireless networking architectures fail to provide adequate resources to efficiently provide optimum range and coverage for wireless network users, and fail to take full advantage of the resources available to satisfy the desire for more bandwidth.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the disclosure are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

FIG. **1** illustrates one embodiment of a virtualization mode and an actual mode for processing wireless signals.

FIG. **2** illustrates a flowchart of steps employed in one embodiment of a method of operation of the system of FIG. **1**.

FIG. **3** illustrates how a virtual MAC and virtual PHY are coordinated to manage actual MAC and PHY layers.

FIG. **4** illustrates how the system of FIG. **2** manages signal processing by determining which resources are available.

FIGS. **5**A and **5**B illustrate alternative ways to manage one embodiment of a variable-duplex link.

FIG. **6** illustrates one embodiment of a variable duplex link that is configurable to manage transmit and receive process cycles, including preset process cycle configurations of different types.

FIG. **7** illustrates one embodiment of a system for wirelessly extending range of a wireless network linearly from one access point to another.

FIG. **8** illustrates a wireless management system that utilizes a virtual MAC and virtual PHY to wirelessly and adaptively manage and control multiple radios in a given wireless access point.

FIG. **9** illustrates a flowchart of steps for one embodiment of a method of wirelessly accessing a wireless network, consistent with the systems shown in FIGS. **1** and **2**.

FIG. **10**A-**10**C illustrate embodiments of a system for wirelessly extending range of a wireless network radially from one access point to other access points.

FIG. **11** illustrates one embodiment of multiple wireless management systems that cooperate to allocate transceiver resources between users.

DETAILED DESCRIPTION

Embodiments of wireless networking systems, wireless transceivers and associated methods are disclosed herein. In one embodiment, a wireless networking system is disclosed. The wireless networking system includes an application layer associated with one or more applications having a wireless bandwidth requirement. A first wireless transceiver resource associated with an actual MAC layer and PHY layer is employed. The first wireless transceiver resource has a first bandwidth availability up to a first actual bandwidth. A second wireless transceiver resource associated with the actual MAC layer and the PHY layer is employed. The second wireless transceiver resource has a second bandwidth availability up to a second actual bandwidth. A processing layer evaluates the wireless bandwidth requirement and the first and second bandwidth availabilities of the wireless transceiver resources. The processing layer includes a bandwidth allocator to allocate at least a portion of each of the first and second actual bandwidths to virtual MAC and virtual PHY layers, and to satisfy the application layer wireless bandwidth requirement.

In a further embodiment, a method of a method of operating a wireless transceiver system is disclosed. The wireless transceiver system includes an application layer, actual MAC and PHY layers, and a processing layer between the actual MAC and PHY layers. The method includes evaluating, with processing logic, application bandwidth requirements of applications associated with the applications layer. A virtual MAC layer and a virtual PHY layer are defined between the processing layer and the actual MAC and PHY layers. A bandwidth allocator allocates multiple wireless transceiver resources in the actual MAC and PHY layer to be controlled by the virtual MAC and PHY layer to satisfy the application bandwidth requirements. A stream of processed data is transferred via a wireless link with the allocated wireless transceiver resources.

In yet another embodiment, a wireless transceiver for coupling to a wireless duplex link is disclosed. The wireless transceiver includes programmable storage, a transmitter and a receiver. The transmitter couples to the programmable storage and transmits data along a wireless link during a first portion of a programmed data transfer cycle. The receiver couples to the programmable storage and receives data from the wireless link during a second portion of the programmed data transfer cycle. The wireless link exhibits an asymmetric transmit/receive profile based on information stored in the programmable storage.

Referring to FIG. **1**, one embodiment of a wireless networking system, generally designated **100**, is shown in an abstract "layer" context. Generally speaking, the system may involve a WiFi network, a mobile wireless network, or a combination of the two. The network includes an application layer "APP", at **102**, with one or more data-intensive software applications "APP A"-"APP D." The individual applications, for example, may have different peak bandwidth requirements in terms of data transfer rates. Thus, for instance, application APP A may have a peak bandwidth requirement of 450 Megabits per second (Mbps), while application APP D may have a peak bandwidth requirement of 750 Mbps.

Further referring to FIG. **1**, the application layer **102** cooperates with a process layer, at **104**. The process layer includes a decision block **106** that interfaces with a processing block **108**. The decision block determines the size and type of data stream being received, and the type of processing necessary to put the stream in a format where it is capable of being transmitted. The processing block processes the data stream as determined by the decision block, and couples to an ultra-streaming block **110**. The ultra-streaming block manages the processing of signal streams or sub-streams given the available resources (memory, processing speed, number of available radios, etc.), and packetizes sufficiently processed streams or sub-streams. The ultra-streaming block feeds data to and from an RF block **112**. While not explicitly shown in FIG. **1**, the ultra-streaming block carries out a monitoring function, more fully described below, that feeds back wireless resource availability to the decision block **106**. Various ways for determining availability of resources include common memory, host interfaces, common threads, and/or queues or other data structures.

The decision block **106**, processing block **108** and ultra-streaming block **110** together form a virtual MAC layer **111**. The RF block **112** forms a virtual PHY layer. As more fully described below, the virtual MAC and PHY layers enable simultaneous allocation of multiple PHY resources for different signal types associated with different applications. As a result, the wireless networking system **100** exhibits significant performance improvements and efficiency advantages.

With continued reference to FIG. **1**, the wireless networking system **100** includes an actual media access control (MAC) layer, at **114**, and an actual physical (PHY) layer, at **116**. The actual MAC layer **114** generally includes software resources capable of controlling one or more transceiver resources **118** that are at the actual PHY layer, such as various radios and receivers. The actual PHY layer **116** may include multiple transceiver resources corresponding to multiple radios, each with an actual data transfer capability, or bandwidth.

The actual PHY layer transceivers may transmit and receive data consistent with a variety of signal protocols, such as High Definition Multimedia Interface (HDMI) consistent with the IEEE 802.11 Standard, Multiple-In Multiple-Out (MIMO), standard Wi-Fi physical control layer (PHY) and Media Access Control (MAC) layer, and existing IP protocols. Additionally, extremely high bandwidth applications such as Voice Over IP (VOIP), streaming audio and video content, multicast applications, convergent and ad-hoc network environment may employ signal protocols consistent with the wireless network system described herein. Additionally, the wireless networking system may be employed and/or embedded into a variety of electronic devices, including wireless access points, base stations, handhelds, tablets, computers, telephones, televisions, DVD players, BluRay players, media players, storage devices, or any such devices that use wireless networks to send and receive data including stand-alone add-on devices such as "dongles" that serve as wireless interfaces between devices.

In operation, and referring to FIG. **2**, the wireless networking system generally determines an overall wireless bandwidth demand or requirement from one or more applications associated with the application layer **102**, at **202**. FIG. **1** illustrates one example, with Application A demanding a peak bandwidth of 450 Mbps, and Application D requiring a peak bandwidth of 740 Mbps. At **204**, the process layer **104** determines available resources in the actual MAC and PHY layers **114** and **116**, and allocates the available resources to satisfy the bandwidth demands, at **206**.

Using the same example shown in FIG. **1**, and assuming that all of the PHY transceivers are available, each PHY transceiver **118** is capable of providing a transmit/receive bandwidth of 300 Mbps. Grouping the entire bandwidth of one transceiver with half the bandwidth of a second satisfies the bandwidth demand for Application A. In a similar manner, allocating the bandwidths of two transceivers, and half the bandwidth of a third transceiver satisfies the bandwidth demand for Application D. The allocating is managed by defining the virtual MAC/PHY layers **111** and **112** with the allocated resources, at **208**.

FIG. **3** illustrates how, in one embodiment, elements associated with the process layer **104** can define a virtual MAC management layer **302** and a virtual PHY layer **304** to enable the sharing of multiple transceiver resources in a way sufficient to satisfy the bandwidth requirements of multiple applications running simultaneously. The virtual MAC and PHY layers manage signals from one or more applications before sending the signals to the actual MAC and PHY layers. The virtual MAC management layer **302** may include the decision block **106**, the processing block **108** and the ultra-streaming block **110**. The virtual PHY layer **304** may include the RF block **112**, shown as multiple RF blocks to denote the virtual use of two sets of allocated transceiver resources. For one embodiment, the RF block(s) communicate directly with the ultra-streaming block about actual resource availability, and the ultra-streaming block sends the information back to the decision block in the virtual MAC layer. Alternatively, the virtual PHY RF block may directly communicate with the virtual MAC decision block and/or the processing block.

Referring now to FIG. **4**, defining the virtual MAC and PHY layers **302** and **304** involves an evaluation of available transceiver resources to meet peak bandwidth demands of applications running in the application layer. One or more applications, such as "Application A" and "Application B", may be initially supported with transceiver resources "Device 1" and "Device 2" through an initialization or training process at startup. The virtual MAC **302** interfaces with the virtual PHY **304** to determine device availability. This further involves a determination at the PHY layer as to the actual availability of the initially assigned transceiver resources. Should a given resource be unavailable, such as through insufficient bandwidth or having an existing assignment, a replacement resource may be identified and assigned. Availability monitoring may be carried out at initialization, as described above, or through periodic or continuous updating based on environmental conditions or through random on demand programming. Adaptively managing the actual resources provides efficient utilization of resources and power.

For one embodiment, the virtual MAC **302** and virtual PHY **304** may be employed to control respective transmit and receive times (also referred to as an RF cycle) for a transceiver coupled to a variable duplex wireless link. FIG. **5**A illustrates a way of ensuring an RF cycle that has a transmit time equal to a receive time, such that a first amount of data is transmitted along a given link that is equal to a second amount of data that is received along the link. A physical resource PHY **502**, such as a wireless transceiver, is shown coupled to a transmit buffer **504** and a receive buffer **506**. By providing transmit buffer storage that is equal to the receive buffer storage, the amount of data transmitted during both portions of the cycle is equal (since the transceiver generally transmits and receives the entire contents of a given buffer before switching to the next portion of the cycle).

While equal transmit and receive portions of the RF cycle may be beneficial in some circumstances, allocating different PHY resources for different applications, as described above, may benefit from asymmetric wireless links, where the transmit or receive times may be different to optimize wireless data traffic. FIG. **5**B illustrates one embodiment of a variable duplex link that includes a transmit buffer **504** that is larger than a receive buffer **506**. A programmable register **508** provides a way to specify the storage capacities of each of the buffers, thus enabling control of the respective transmit and receive time. In another embodiment, the programmable register may include storage to specify precise transmit and receive times for the RF cycle in addition to, or instead of varying the buffer sizes. For some embodiments, sub-programmable mask intervals may be programmed which disable a given transmitter or receiver during the pre-programmed transmit or receive time.

FIG. **6** illustrates one embodiment of the wireless networking system, described above, utilizing the variable duplex link to optimize uplink (transmit) and downlink (receive) data transfer efficiency for a given application. As shown in FIG. **6**, a decision block **602** associated with a virtual MAC **604** detects application types, APP A and APP B, for which a preset transmit/receive cycle ratio has been assigned. A processing block **606** processes the substream signals together with the preset cycle ratio information. A virtual PHY **608**, configures available devices to the preset cycle ratio in terms of either configuring transmit and receive buffer sizes, and/or configuring actual transmit and receive cycle times.

The virtual MAC and PHY layers **604** and **608** may also be used to reconfigure, or update, the RF cycle times of the link periodically or continuously. Additionally, random on-demand programming may be employed to reconfigure the link. By monitoring parameters associated with the link, a predictive model of optimal link operation may be adaptively generated, resulting in enhanced link operability.

Those skilled in the art will appreciate that the embodiments described above enable wireless networking systems to operate at higher levels of performance and with better efficiencies. By employing a virtual MAC and virtual PHY between an application layer and an actual MAC and PHY layer, wireless transceiver resources may be allocated more efficiently to handle various data bandwidth requirements from different applications. Additionally, by selectively employing a variable duplex link, data transfers may be further optimized through finer control of link transmit and receive times.

When received within a computer system via one or more computer-readable media, such data and/or instruction-based expressions of the above described circuits may be processed by a processing entity (e.g., one or more processors) within the computer system in conjunction with execution of one or more other computer programs including, without limitation, net-list generation programs, place and route programs and the like, to generate a representation or image of a physical manifestation of such circuits. Such representation or image may thereafter be used in device fabrication, for example, by enabling generation of one or more masks that are used to form various components of the circuits in a device fabrication process.

Further embodiments of wireless networking systems, wireless transceivers and associated methods are disclosed herein. In one embodiment, a wireless networking system is disclosed. The system includes a first wireless access point having a first coverage area. The first wireless access point includes a first wireless transceiver to access a wireless network and a second wireless transceiver coupled to the first wireless transceiver. A second wireless access point has a second coverage area. The second wireless access point includes a third wireless transceiver for establishing a wireless link with the second wireless transceiver, and a fourth wireless transceiver coupled to the third wireless transceiver to provide user access to the wireless link. User access to the wireless link accesses the wireless network via the second and first wireless transceivers.

In a further embodiment, a method of providing wireless network access to a user is disclosed. The method includes accessing a wireless network with a first wireless transceiver associated with a first wireless access point. The first wireless access point has a first coverage area bounded by a range of a first broadcast transceiver associated with the first wireless access point. Wireless access to the wireless network is enabled within the first coverage area with the first broadcast transceiver. A wireless link is established between the first wireless access point and a third wireless transceiver associated with a second wireless access point. The second wireless access point has a second coverage area bounded by a fourth wireless transceiver. The fourth wireless transceiver is in communication with the third wireless transceiver. Access to the wireless network from within the second coverage area is enabled via the fourth wireless transceiver.

In yet another embodiment, a wireless access point for use in a wireless networking system, the wireless access point includes a first wireless transceiver to establish a wireless link to a wireless network. A second wireless transceiver provides wireless access to the wireless link within a first coverage area. A third wireless transceiver establishes a wireless link to a second wireless access point. Processing logic controls each of the first, second and third wireless transceivers.

Referring to FIG. **7**, one embodiment of a wireless networking system is shown, generally designated **610**, that increases the range of wireless network access. The wireless networking system **610** includes multiple wireless access points, or nodes, **612**A-**612**E. The nodes may be positioned linearly, such as in serial or wirelessly daisy-chained arrangement, to linearly extend wireless network access across multiple access point coverage zones. A similar embodiment that extends coverage radially is described below with reference to FIGS. **10**A-**10**C.

With continued reference to FIG. **7**, for one specific embodiment, node **612**A includes multiple radios A1 and A2. Radio A1 is configured as a receiver/transmitter (transceiver) that exhibits a wireless transceiver range, denoted by the circle at **614**, to receive and transmit signals to a network, such as the Internet **615**. Note that for purposes of clarity, each node is shown in FIG. **7** as having a range defined by the range of one of the radios. Radio A1, while acting as a receiver/transmitter (often referred to herein as a transceiver) is also able to broadcast and receive signals within its coverage area to users that are in the area **614**, thereby serving as a wireless access point for that area. User U1 thus may access the Internet via radio A1. Radio A1 also communicates with a relay radio A2, which may be disposed near the periphery of the range **104** of radio A1. Relay radio A2 has a similar range as radio A1, and is able to communicate with radio B1 that is associated with node **612**B. For some embodiments, the relay radio (such as radio A2) for a given node is assigned to one or more dedicated transceivers (such as B1) associated with respective adjacent nodes. Additionally, in general, the transceivers of a given node can communicate to any of the transceivers available in adjacent nodes.

Further referring to FIG. **7**, node **612**B includes three radios, one to establish communication with radio A2 of node **612**A, a second radio B2 to act as a relay to a third node **612**C, and a third radio B3 to act as a wireless access point to a second user U2 within the node **102**B. The third node **102**C includes a first radio C1 to communicate with the second radio B2 of the second node **612**B, and a second radio C2 to provide wireless access to a third user U3 within the access coverage area of the third node **612**C. Thus, with communication links established from the Internet to radio A1, to radio A2, to radio B1 to radio B2 to radio C1 and to radio C2, the user U3 is able to access the Internet wirelessly even though the distance between the user U3 to the first wireless access point A1 exceeds the coverage or range of radio A1.

Each node **612**A-**612**C described above, may be configured differently depending on the available resources and bandwidth demands. Thus, a given radio may handle multiple tasks to receive and broadcast simultaneously, if the bandwidth demands are relatively low, or handle a single task, such as relay radio A2, if the bandwidth demand necessitates the need for additional wireless transceiver resources.

To manage the allocation and configuration of wireless transceiver resources, each node employs a management system, such as one embodiment shown in FIG. **8**, and generally designated **710**. The management systems for multiple nodes thus forms distributed logic that cooperate to efficiently manage bandwidth utilization for users. Further details of the management system for a variety of applications are disclosed in U.S. Pat. No. 9,788,305, titled METHOD AND APPARATUS FOR PROCESSING BANDWIDTH INTENSIVE DATA STREAMS USING VIRTUAL MEDIA ACCESS CONTROL AND PHYSICAL LAYERS, filed Oct. 29, 2014, and expressly incorporated herein by reference.

Further referring to FIG. **8**, one specific embodiment of the management system **710**, is shown in a networking "layer" context. Generally speaking, the wireless management system may be configured for coupling an available transceiver resource to a WiFi network, a mobile wireless network, or a combination of the two. The management system **710** includes an application layer "APP", at **712**, with one or more data-intensive software applications "APP A"-"APP D." The individual applications, for example, may have different peak bandwidth requirements in terms of data transfer rates. Thus, for instance, application APP A may have a peak bandwidth requirement of 450 Megabits per second (Mbps), while application APP D may have a peak bandwidth requirement of 750 Mbps.

Further referring to FIG. **8**, the application layer **712** cooperates with a process layer, at **714**. The process layer includes a decision block **716** that interfaces with a processing block **718**. The decision block determines the size and type of data stream being received, and the type of processing necessary to put the stream in a format where it is capable of being transmitted. The processing block processes the data stream as determined by the decision block, and couples to an ultra-streaming block **720**. The ultra-streaming block manages the processing of signal streams or sub-streams given the available resources (memory, processing speed, number of available radios, etc.), and packetizes sufficiently processed streams or sub-streams. The ultra-streaming block feeds data to and from an RF block **722**. While not explicitly shown in FIG. **8**, the ultra-streaming block carries out a monitoring function, more fully described below, that feeds back wireless resource availability to the decision block **716**. Various ways for determining availability of resources include common memory, host interfaces, common threads, and/or queues or other data structures.

The decision block **716**, processing block **718** and ultra-streaming block **720** together form a virtual MAC layer **621**. The RF block **722** forms a virtual PHY layer. The virtual MAC and PHY layers enable simultaneous allocation of multiple PHY resources for different signal types associated with different applications. Transceiver configurations may be applied at initialization of the system, periodically during normal operation, or randomly on demand during operation. As a result, the most efficient path for wireless access between a given user and the wireless network is paved. The wireless networking system **710** thus exhibits significant performance improvements and efficiency advantages.

With continued reference to FIG. **8**, the wireless management system **710** includes an actual media access control (MAC) layer, at **724**, and an actual physical (PHY) layer, at **726**. The actual MAC layer **724** generally includes software resources capable of controlling one or more transceiver resources **728** that are at the actual PHY layer, such as various radios and receivers. The actual PHY layer **726** may include multiple transceiver resources corresponding to multiple radios, each with an actual data transfer capability, or bandwidth.

The actual PHY layer transceivers may transmit and receive data consistent with a variety of signal protocols, such as High Definition Multimedia Interface (HDMI) consistent with the IEEE 802.11 Standard, Multiple-In Multiple-Out (MIMO), standard Wi-Fi physical control layer (PHY) and Media Access Control (MAC) layer, and existing IP protocols. Additionally, extremely high bandwidth applications such as Voice Over IP (VOIP), streaming audio and video content, multicast applications, convergent and ad-hoc network environment may employ signal protocols consistent with the wireless network system described herein. Additionally, the wireless management system may be employed and/or embedded into a variety of electronic devices, including wireless access points, base stations, handhelds, tablets, computers, telephones, televisions, DVD players, BluRay players, media players, storage devices, or any such devices that use wireless networks to send and receive data including stand-alone add-on devices such as "dongles" that serve as wireless interfaces between devices.

FIG. **9** illustrates a flowchart that shows generic steps carried out during operation of the wireless networking system of FIG. **7**. At **812**, the first node **612**A (FIG. **7**) accesses a wireless network, such as the Internet **615**, with a first radio or transceiver A1. A second transceiver A2, establishes a wireless link with the first transceiver A1, at **814**. The second transceiver may then act as a relay to establish a further link with a radio in a different node, such as radio B1 in node **612**B. The wireless network may then be accessed through the different node **612**B via the wireless link (between radios B1 and A2) and the first access point, at **816**. By employing a plurality of transceivers at each of the nodes that run the Ultra Streaming engine to allocate their available resources, either at initialization as configurable, or while in operation periodically, or dynamically in random demand while in operation, the most efficient path for wireless access is accomplished. This results in increased range and coverage for a given wireless network, and it's Internet access.

FIGS. **10**A-**10**C illustrate a further embodiment of a wireless networking system, generally designated **910**, that is similar to the system of FIG. **7**, but configured with various nodes **912**A-**912**G that are positioned in a relative manner to extend coverage radially, rather than linearly. Each of the nodes includes a wireless management system, such as that shown in FIG. **8** and described above.

Further referring to FIG. **10**A, a first node **912**A includes radios A1-A7, with radio A1 acting as an originating access point for a local network signal, such as the Internet **915**. The remaining radios A2-A7 may then be configured to communicate with specified adjacent nodes. The adjacent nodes have respective coverage zones that overlap the primary node **912**A radially outwardly. Thus, by encircling the primary node with the other nodes, the corresponding coverage area may be increased dramatically.

FIG. **10**B illustrates one configuration where radio A1 acts as the originating radio to communicate with the local wireless network, and radio A2 communicates the network signal as a relay with radios B2 and C2 of nodes **912**B and **912**C. Radios B1 and C1 of each respective node broadcast wireless access to users within the respective coverage zones, bounded by coverage rings **914** and **916** associated with each respective node **912**B and **912**C. Similar arrangements are managed with radio A3 communicating with radios D2 and E2, and radios A4 and A5 communicating with F2 and G2, respectively. To optimize coverage radially, the nodes **912**B-**912**G are positioned radially around the primary node **912**A in a honeycomb structure. The resulting coverage boundary, represented by the coverage circle **408**, is significantly larger than the originating access coverage area (represented by ring **410**) provided by the broadcast radio associated with node **402**A by itself.

FIG. **10**C illustrates different assignments of the radios in the wireless networking system of FIG. **10**A managed by the wireless management system **910** of each node **912**A-**912**G. The assignments and radio configurations may be defined and managed during an initialization process, periodically during operation, or randomly on demand depending on the bandwidth demands of the system. Thus, if bandwidth demands are higher in nodes **912**B and **912**C, then instead of sharing the bandwidth of radio A2 with nodes **912**B (radio B2) and **912**C (radio C2), such as the arrangement of FIG. **10**B, dedicated relay radios A2 and A3 may be assigned to each of those nodes so that maximum bandwidth may be provided to each, resulting in radio A2 communicating with radio B2 and radio A3 communicating with radio C2 (FIG. **10**C).

For some embodiments, whether the wireless networking system is configured as a linear or radial architecture, there may be multiple transceivers assigned to a wireless node, and each node may have multiple transceivers assigned to a given user. FIG. **11** illustrates how multiple wireless management systems cooperate to efficiently allocate transceiver resources in such a situation. A first node management system **962** may control transceiver resources A1 and A2 within a first node. A second management system **964** may control transceiver resources B1, B2, and B3. The management systems **962** and **964** communicate with each other to determine the optimal resource allocation to service respective local users, at **958** and **960**.

Thus, for the example shown in FIG. **11**, the first local user **9587** within the coverage of the first node may need bandwidth that may be sufficiently provided by transceiver A1 alone. The second local user **960**, positioned within the vicinity of both the first and second nodes, may be assigned transceiver A2 from the first node, and transceiver B2 from the second node, thereby having access to twice the bandwidth. Other examples may involve partial transceiver allocations, where a portion of the transceiver bandwidth is allocated to a first user, and a second portion of the bandwidth allocated to a second user.

In some embodiments, a given wireless link may be configured as a variable duplex link. Each wireless management system may task the virtual MAC and virtual PHY to control respective transmit and receive cycles for one or more of the wireless transceivers. Varying the transmit and/or receive times may be accomplished in various ways, such as through programmable buffer resources and/or through programmable transmit and receive times. Further detail of such a variable duplex wireless link may be found in U.S. Pat. No. 9,788,305, titled METHOD AND APPARATUS FOR PROCESSING BANDWIDTH INTENSIVE DATA STREAMS USING VIRTUAL MEDIA ACCESS CONTROL AND PHYSICAL LAYERS, filed Oct. 29, 2014, and expressly incorporated herein by reference.

Those skilled in the art will appreciate that the embodiments described above enable efficient wireless access to wireless networking systems by users that might be outside the range of a single wireless access point. By employing linear and/or radial wireless access system architectures, and configuring available wireless transceiver resources optimally within each node, a given wireless network may be accessed with greater bandwidth and more efficiently.

When received within a computer system via one or more computer-readable media, such data and/or instruction-based expressions of the above described circuits may be processed by a processing entity (e.g., one or more processors) within the computer system in conjunction with execution of one or more other computer programs including, without limitation, net-list generation programs, place and route programs and the like, to generate a representation or image of a physical manifestation of such circuits. Such representation or image may thereafter be used in device fabrication, for example, by enabling generation of one or more masks that are used to form various components of the circuits in a device fabrication process.

In the foregoing description and in the accompanying drawings, specific terminology and drawing symbols have been set forth to provide a thorough understanding of the present invention. In some instances, the terminology and symbols may imply specific details that are not required to practice the invention. For example, any of the specific numbers of bits, signal path widths, signaling or operating frequencies, component circuits or devices and the like may be different from those described above in alternative embodiments. Also, the interconnection between circuit elements or circuit blocks shown or described as multi-conductor signal links may alternatively be single-conductor signal links, and single conductor signal links may alternatively be multi-conductor signal links. Signals and signaling paths shown or described as being single-ended may also be differential, and vice-versa. Similarly, signals described or depicted as having active-high or active-low logic levels may have opposite logic levels in alternative embodiments. Component circuitry within integrated circuit devices may be implemented using metal oxide semiconductor (MOS) technology, bipolar technology or any other technology in which logical and analog circuits may be implemented. With respect to terminology, a signal is said to be "asserted" when the signal is driven to a low or high logic state (or charged to a high logic state or discharged to a low logic state) to indicate a particular condition. Conversely, a signal is said to be "deasserted" to indicate that the signal is driven (or charged or discharged) to a state other than the asserted state (including a high or low logic state, or the floating state that may occur when the signal driving circuit is transitioned to a high impedance condition, such as an open drain or open collector condition). A signal driving circuit is said to "output" a signal to a signal receiving circuit when the signal driving circuit asserts (or deasserts, if explicitly stated or indicated by context) the signal on a signal line coupled between the signal driving and signal receiving circuits. A signal line is said to be "activated" when a signal is asserted on the signal line, and "deactivated" when the signal is deasserted. Additionally, the prefix symbol "/" attached to signal names indicates that the signal is an active low signal (i.e., the asserted state is a logic low state). A line over a signal name (e.g., '<signalname>') is also used to indicate an active low signal. The term "coupled" is used herein to express a direct connection as well as a connection through one or more intervening circuits or structures. Integrated circuit device "programming" may include, for example and without limitation, loading a control value into a register or other storage circuit within the device in response to a host instruction and thus controlling an operational aspect of the device, establishing a device configuration or controlling an operational aspect of the device through a one-time programming operation (e.g., blowing fuses within a configuration circuit during device production), and/or connecting one or more selected pins or other contact structures of the device to reference voltage lines (also referred to as strapping) to establish a particular device configuration or operation aspect of the device. The term "exemplary" is used to express an example, not a preference or requirement.

While the invention has been described with reference to specific embodiments thereof, it will be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention. For example, features or aspects of any of the embodiments may be applied, at least where practicable, in combination with any other of the embodiments or in place of counterpart features or aspects thereof. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A method of improving the performance of a wireless networking device, comprising the steps of:

connecting an application interface to a processing interface, the application interface being associated with a first application, the first application providing, when the wireless networking device is being used, a first data stream and having a first wireless bandwidth requirement;

connecting first and second actual MAC interfaces to the processing interface;

connecting first and second actual PHY interfaces respectively to the first and second actual MAC interfaces;

respectively associating first and second wireless transceivers with the first and second actual PHY interfaces, wherein each one of the first and second wireless transceivers (i) is suitable for use in a wireless local area network, (ii) has a first and second bandwidth availability up to a first and second actual bandwidth, and (iii) is adapted to emit radio waves in first and second different bands of frequencies;

forming in the processing interface (i) at least one virtual MAC interface and (ii) first and second virtual PHY interfaces that, during operation of the wireless networking device, feed information regarding the bandwidth availabilities of the first and second wireless transceivers back to the at least one virtual MAC interface;

wherein the processing interface is configured to, when the wireless networking device is being used, in a manner transparent to any layer of the wireless networking device above the processing interface,

(a) request or create (i) a first association between a recipient and the first actual MAC and PHY interfaces and (ii) a second association between the recipient and the second actual MAC and PHY interfaces, and

(b) (i) identify at least one portion of each one of the first and second bandwidth availabilities of the first and second wireless transceivers, and (ii) evaluate the identified bandwidth availabilities of the first and second wireless transceivers with respect to the first bandwidth requirement of the first application;

wherein, if the first bandwidth requirement is at least partially satisfied by the bandwidth availabilities of the first and second wireless transceivers, preparing the first data stream for simultaneous transmission to the recipient from both of the first and second wireless transceivers using a specific subset of frequencies corresponding to the identified at least one portions of their available bandwidth and causing the prepared first data stream to be transmitted from the first and second wireless transceivers to thereby at least partially satisfy the first wireless bandwidth requirement of the first application; and

wherein the wireless networking device's utilization of the available bandwidth of the first and second wireless transceivers does not prevent other wireless networking devices from utilizing a range of frequencies corresponding to the remaining portion of the bandwidth availability of the first and second wireless transceivers for data transmission purposes at the same time that processed data is being sent from the first and second wireless transceivers.

2. The method of claim **1**,

wherein the application interface is associated with a second application, the second application providing, when the wireless networking device is being used, second data stream and having a second wireless bandwidth requirement;

wherein the processing interface is configured to, when the wireless networking device is being used, in a manner transparent to any layer of the wireless networking device above the processing interface, (i) prepare the first and second data streams for simultaneous transmission to the recipient from both of the first and second wireless transceivers using a specific subset of frequencies corresponding to the identified at least one portions of their available bandwidth, and (ii) cause the prepared first and second data streams to be simultaneously transmitted from the first and second wireless transceivers to thereby at least partially satisfy the first and second wireless bandwidth requirements of the first and second applications.

3. The method of claim 2,

wherein, if the identified at least one portion of the bandwidth of the first wireless transceiver becomes unavailable during use of the wireless networking device or if it has an unidentified portion of bandwidth availability that is greater than its identified at least one portion of bandwidth availability during use of the wireless networking device, the processing interface is adapted to, as a result of the unavailability or the increased bandwidth availability and in a manner transparent to any layer of the wireless networking device above the processing interface,

(i) identify at least one new portion of the bandwidth of the first wireless transceiver that is available for communication and then select that wireless transceiver,

(ii) prepare the first and second data streams, without requiring the disassociation of the recipient from the actual MAC and PHY interfaces associated with any wireless transceiver, for transmission to the recipient from the first and second wireless transceivers using a specific subset of frequencies corresponding to the newly identified at least one portion of available bandwidth of the first wireless transceiver as well as the identified at least one portion of available bandwidth of the second wireless transceiver, and

(iii) cause the first and second prepared data streams to be transmitted to the recipient from the first and second wireless transceivers, without requiring the disassociation of the recipient from the actual MAC and PHY interfaces of any wireless transceiver, to thereby continue to at least partially satisfy the first and second wireless bandwidth requirements of the first and second applications.

4. The method of claim 3,

wherein, if the identified at least one portion of the bandwidth of the second wireless transceiver becomes unavailable during use of the wireless networking device or if it has an unidentified portion of bandwidth availability that is greater than its identified at least one portion of bandwidth availability during use of the wireless networking device, the processing interface is adapted to, as a result of the unavailability or the increased bandwidth availability and in a manner transparent to any layer of the wireless networking device above the processing interface,

(i) identify at least one new portion of the bandwidth of the second wireless transceiver that is available for communication and then select that wireless transceiver,

(ii) prepare the first and second data streams, without requiring the disassociation of the recipient from the actual MAC and PHY interfaces associated with any wireless transceiver, for transmission to the recipient from the first and second wireless transceivers using a specific subset of frequencies corresponding to the identified at least one portion of the bandwidth availability of the first wireless transceiver and the newly identified at least one portion of available bandwidth of the second wireless transceiver, and

(iii) cause the first and second prepared data streams to be transmitted to the recipient from the first and second wireless transceivers, without requiring the disassociation of the recipient from the actual MAC and PHY interfaces of any wireless transceiver, to thereby continue to at least partially satisfy the first and second wireless bandwidth requirements of the first and second applications.

5. The method of claim 4, further comprising the steps of:

connecting a third actual MAC interface to the processing interface;

connecting a third actual PHY interface to the third actual MAC interface;

associating a third wireless transceiver with the third actual PHY interface, wherein the third wireless transceiver (i) is suitable for use in a wireless local area network, (ii) has a third bandwidth availability up to a third actual bandwidth, and (iii) is adapted to emit radio waves in a third band of frequencies;

forming in the processing interface a third virtual PHY interface that, during operation of the wireless networking device, feeds information regarding the bandwidth availability of the third wireless transceiver back to the at least one virtual MAC interface;

wherein the processing interface is configured to, when the wireless networking device is being used, in a manner transparent to any layer of the wireless networking device above the processing interface, request or create a third association between the recipient and the third actual MAC and PHY interfaces;

wherein, if the first and second bandwidth requirements are not at least partially satisfied by the bandwidth availabilities of the first and second wireless transceivers, (i) identifying at least one portion of the bandwidth availability of the third wireless transceiver, (ii) preparing the first and second data streams for simultaneous transmission to the recipient from all of the identified at least one portions of the bandwidths of the first, second and third wireless transceivers using a specific subset of frequencies corresponding to the identified at least one portions of their available bandwidth and (iii) causing the prepared first and second prepared data streams to be transmitted from the first, second and third wireless transceivers to thereby at least partially satisfy the first and second wireless bandwidth requirements of the first and second applications; and

wherein the wireless networking device's utilization of the available bandwidth of the first, second and third wireless transceivers does not prevent other wireless networking devices from utilizing a range of frequencies corresponding to the remaining portion of the bandwidth availability of the first, second and third wireless transceivers for data transmission purposes at the same time that processed data is being sent from the first, second and third wireless transceivers.

6. The method of claim 5, wherein the at least one portion of the third bandwidth of the third transceiver comprises a single portion.

7. The method of claim 5, wherein the at least one portion of the third bandwidth of the third transceiver is contiguous.

8. The method of claim 5, wherein the third virtual PHY layer is not contiguous with the virtual MAC interface.

9. The method of claim 5, wherein at least one of the first, second and third wireless transceivers are adapted to com-

municate with a recipient via a variable duplex link that exhibits an asymmetric transmit and receive profile that is programmable.

10. The method of claim **5**, wherein the wireless networking device comprises a first wireless access point that provides access to the internet within a first coverage area, the processing interface of the first wireless access point being configured to, during operation of the first wireless access point, establish a wireless link to a second wireless access point that has a second coverage area and a processing interface, the processing interfaces of the first and second wireless access points being configured, during their operation, to communicate with each other regarding at least one aspect of operation of the first wireless access point.

11. The method of claim **10**, wherein the processing interface of the first wireless access point cooperates with the processing interface of the second wireless access point to define a distributed processing logic.

12. The method of claim **10**, wherein the aspect of operation of the first wireless access point comprises aggregation of the bandwidth availabilities of the first, second and third wireless transceivers of the first wireless access point in a virtual link.

13. The method of claim **1**, wherein the wireless networking device comprises a wireless access point.

14. The method of claim **1**, wherein the wireless networking device comprises a handheld computing device.

15. The method of claim **14**, wherein the handheld computing device comprises a tablet.

16. The method of claim **1**, wherein each one of the first and second frequency bands is specified in at least one member of the family of IEEE 802.11 standards.

17. The method of claim **16**, wherein the at least one member of the family of IEEE 802.11 standards was in existence as of Oct. 30, 2013.

18. The method of claim **1**, wherein the virtual MAC interface includes a decision block.

19. The method of claim **1**, wherein the virtual MAC interface includes a processing block.

20. The method of claim **1**, wherein the virtual MAC interface includes an ultra-streaming block.

21. The method of claim **1**, wherein each one of the virtual PHY interface includes an RF block.

22. The method of claim **1**, wherein the wireless networking device comprises a telephone.

23. The method of claim **1**, wherein the at least one portion of the first bandwidth of the first transceiver comprises a single portion.

24. The method of claim **1**, wherein the at least one portion of the first bandwidth of the first transceiver is contiguous.

25. The method of claim **1**, wherein the at least one portion of the second bandwidth of the second transceiver comprises a single portion.

26. The method of claim **1**, wherein the at least one portion of the second bandwidth of the second transceiver is contiguous.

27. The method of claim **1**, wherein the first virtual PHY layer is not contiguous with the virtual MAC interface.

28. The method of claim **1**, wherein the second virtual PHY layer is not contiguous with the virtual MAC interface.

29. The method of claim **1**, wherein multiple virtual MAC interfaces are formed in the processing interface.

30. The method of claim **1**, wherein the processing interface includes a bandwidth allocator.

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